FACTORS LIMITING TREE GROWTH IN SOUTHERN ILLINOIS UNDER SMCRA[1]

by

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Abstract. Tree survival and height growth of green/white ash (Fraxinus pennsylvanica/F. americana), black walnut (Juglans nigra), and red oak (Quercus rubra) were determined in 1988-89 on three mine sites in southern Illinois. All sites had been graded, were found to be compacted, and had dense ground covers of tall fescue (Festuca arundinacea) and other herbaceous species. Trees were established in 1981 and 1982 with the ash as bare-root seedlings and the walnut and oak as seedlings and as seed. Survival and height growth were low at all three graded and compacted sites. In one study herbicide application enhanced tree performance and fertilizer had little effect. Trees grew more poorly in tall fescue than in other cover types. The other two studies were notable for animal damage to trees. Red oak was most severely damaged by voles, and black walnut by deer.

Additional Key Words: Compaction, stripmine, reclamation, reforestation, green ash (Fraxinus pennsylvanica Marsh.), black walnut (Juglans nigra L.), red oak (Quercus rubra L.), tall fescue (Festuca arundinacea Schreb., selection Ky-31), herbicide, animal damage, deer, vole, ground cover.

Introduction

Trees have been extensively planted on mined lands, more than seventeen million in Illinois alone prior to 1968. By the time Public Law 95-87 "Surface Mining Control and Reclamation Act of 1977" (SMCRA) was passed, tree planting had declined from the major to a relatively minor post-mining land use. Under SMCRA the number of acres annually planted to trees increased greatly. Many persons with experience from the pre-law operations, however, have a perception that the tree planting under SMCRA has been less successful than earlier. Data from pre-law plantings at several ages for two of the mines in this study are available from publications and are compared to current growth and survival rates. Any such comparisons must be approximate because of differences in planting dates of thirty or more years, with associated differences in weather conditions and other growth factors.

Major impacts of SMCRA on planting sites have included grading, replacement of surface soils, and establishment of planted ground covers. Numerous studies have shown that these graded sites have high soil

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Table 1. Site description, management, and planting plan for green/white ash, black walnut, and red oak at CONSOL, Freeman and Sahara. The ash planted was nominally green at CONSOL and Freeman and white at Sahara. Green ash was later reported at Sahara. Ash was planted only as seedlings, and black walnut and red oak were planted as both seed and seedlings at Freeman and Sahara.

	Mine		
Site Features	*CONSOL*	*Freeman*	*Sahara*
Year mined	1976	1978	1978
Equipment	Wheel and shovel	Wheel and shovel	Shovel
Grading	Nearly flat-dozers	15% slope-dozers	Slight slope-dozers
Topsoil depth	8+ inches	None	10+ inches
Subsoil depth	40 inches	Remined cast overburden	16 inches
Bulk density	1.8 gcm^{-3}	1.8 gcm^{-3}	1.6 gcm^{-3}
Typical pH	8.2	> 7.0	5.0 - 7.4
Available P	Low	Very low P and K	Low
Fertilizer	9g tablet (22-8-2) per tree	112 $kgha^{-1}$ (33-44-0)	As required under SMCRA
Ground cover in 1989	See Table 2[1]	Tall fescue, some[2] alfalfa	Tall fescue[3]
Herbicides	Amitrol-T and simazine: 4-foot band	Roundup and simazine: 5-foot circle @ tree	Roundup and simazine: 5-foot circle @ tree
Established	1981	1981, 1982	1981, 1982
Trees/acre	1360	650	650
Row length	100 trees	12 trees	50 trees
Plot numbers	4 (split)	40	6
Total trees	1200	4800	1300
Planting	Machine	Hand	Hand
Material	Bare-root seedling	Seed and seedling	Seed and seedling
Spacing	4' in row, 8' between rows	2.5m (8.2') by 2.5m	2.5m (8.2') by 2.5m

[1]Raisanen 1982. Seedling mixes in Table 2. Wheat as cover crop. Planted 1980.
[2]Ashby et al. 1988. Seeded tall fescue, alfalfa, and orchard grass with oats as cover crop. Planted 1980.
[3]Kolar et al. 1981. Seeded tall fescue, alfalfa, orchard grass, ladino clover (Trifolium repens). Planted 1980.

bulk density and other indications of compaction from traffic by heavy equipment. Compaction has been shown both indirectly by comparing plant growth on ungraded or ripped minesoils with those graded, and directly to limit root penetration and plant growth (Josiah 1986).

This paper reports still further impacts of practices mandated under SMCRA on tree growth and survival. These include direct effects of ground cover, and indirect effect of ground cover on animal damage to trees. Another observed impact was an effect of slope position on tree growth in contrast to absence of slope effects on pre-law ungraded mined lands.

Materials and Methods

Studies were carried out at the Consolidation Coal Company Burning Star

Mine No. 2 east of Pinckneyville in Perry County, Illinois, the Freeman United Coal Company Fidelity Mine west of DuQuoin in Perry County, Illinois, and the Sahara Coal Company Mine No. 6 west of Harrisburg in Saline County, Illinois. These studies have as a common denominator plantings of green/white ash (Fraxinus pennsylvanica Marsh./F. americana L.), black walnut (Juglans nigra L.), and red oak (Quercus rubra L.). Their performance is compared with one another on each mine site and by species among sites, and for Freeman and Sahara with pre-law plantings. The CONSOL and Sahara studies had respectively a total of 17 and 20 rows of trees per plot. We are reporting on five rows each, including black walnut and red oak planted as seed and as seedlings and green ash planted only as seedlings. Seed was collected locally, and seedlings came from the state nurseries.

The site characteristics, management, plant materials, and planting dates and methods are shown in Table 1. Soils were described at CONSOL and Sahara by a retired SCS soil surveyor (Miles 1989) and at Freeman by Norland (Ashby et al. 1988). Average bulk densities from earlier records were by Shelby tube at CONSOL and sand cone method elsewhere. Tree rows, except where herbicide was an experimental variable, were sprayed with a post-/pre-emergent herbicide mix at or soon after planting. Experimental variables included herbicide, fertilizer, and ground cover at CONSOL, and slope at Freeman. The four ground cover seed mixes at CONSOL are shown in Table 2. Because of the differences in experimental design, tests of significance between sites were not appropriate. Statistical analyses of the height data at CONSOL were carried out as ANOVA with one replication each for herbicide and fertilizer, and four replications for each ground cover. With only one datum per treatment percent survival was not statistically analyzed. The effects of slope on tree growth at Freeman were based on ANOVA with eight replications per five slope positions, and a Scheffe test as appropriate.

Table 2. Herbaceous cover mixes seeded during September 1980 at CONSOL (Raisanen 1982). The species of each mix dominant in 1988-89 is designated by *.

Mix A	Lbs./Ac.
Perennial ryegrass (Lolium perenne)	20
Red clover (Trifolium pratense)	14
*Red top (Agrostis alba)	6
Mix B	
Orchard grass (Dactylis glomerata)	25
Korean lespedeza (Lespedeza stipulacea)	15
*Timothy (Phleum pratense)	5
Mix C	
Orchard grass (Dactylis glomerata)	25
*Birdsfoot trefoil (Lotus corniculatus)	10
Red clover (Trifolium pratense)	10
Mix D	
*Ky. 31 tall fescue (Festuca arundinacea)	20
Alfalfa (Medicago sativa)	15
Orchard grass (Dactylis glomerata)	15
Red clover (Trifolium pratense)	10

Table 3. Survival and average height after 7 or 8 years of green/white ash, black walnut, and red oak on three graded, compacted mine sites with dense ground cover.

Mine Site	Survival (%)			Height (cm)		
	Ash	Walnut	Oak	Ash	Walnut	Oak
CONSOL	62	45	41	309	130	201
Freeman	41	8	2	115	83	61
Sahara	66	41	59	186	84	144

Results

Species performance in these studies is shown by site and species in Table 3. Ash had the greatest survival and height on all sites, while values for black walnut and red oak were substantially lower. Treatment effects were found at CONSOL. For all three tree species, increased survival and growth were found on the herbicided plots (Table 4). Fertilizer did not affect tree survival or height. Ground cover effects were significant for walnut and oak, but not for ash. Tree height, though not survival, was consistently greatest with the birdsfoot trefoil ground cover, and successively less with the redtop, timothy, and fescue cover.

Reasons for the relatively low survival and height growth at Freeman shown in Table 3 will be discussed later. Differences in growth were related to slope position (Table 5). All three species showed a strong trend for greatest survival and height growth on the lower north-facing slope. Tree heights were significantly different by the Scheffe test for the upper and lower slope positions for ash and walnut. The number of surviving red oaks was too low for an ANOVA to be appropriate.

Table 4. Tree survival and average height at CONSOL after 8 years for green ash, black walnut, and red oak as affected by herbicide, fertilizer, and ground cover.

		Survival (%)[1]			Height (cm)[2]		
		Ash	Walnut	Oak	Ash	Walnut	Oak
Herbicide:	+	79	46	59	339	165	237
	-	44	44	23	255	93	110
Fertilizer:	+	62	44	38	302	129	197
	-	60	46	44	316	130	204
Ground cover:	Trefoil	58	46	37	351	180	250
	Redtop	70	57	53	341	129	196
	Timothy	53	39	55	324	119	187
	Fescue	65	38	19	222	80	160

[1] An unknown, apparently small number of trees had been removed with a tree spade for a neighboring golf course.

[2] Heights of all three species were significantly different ± herbicide. A statistically significant difference was found within the tree heights for walnut and oak related to type of ground cover.

Table 5. Slope position effects on survival and height of ash, black walnut, and red oak at Freeman on a 15° north - facing slope after 8 years.

Position	Survival (%)			Height (cm)		
	Ash	Black Walnut	Red Oak	Ash	Black Walnut	Red Oak
Top	34	1	2	86cd[1]	67ab	53
Upper slope	51	4	1	107bc	54b	62
Mid slope	23	4	0	111abc	56b	33
Lower slope	55	20	2	129a	88ab	50
Bottom	70	14	5	126ab	93a	71

[1]Heights within a column that do not have letters in common are significantly different at the 0.05 level. Cell sizes were too small for ANOVA with red oak..

Discussion

A persistent question is how well trees planted on pre-law sites grew compared to trees of equivalent age on post-SMCRA sites. Such comparisons, while highly instructive, are confounded by differences in plot designs, weather after planting, ages at which measurements were taken and reported, and other factors. Approximate comparisons are available for Freeman and Sahara (Table 6). At Freeman the 8-year heights on the pre-law ungraded banks were greater than on the post-SMCRA plots (Table 3). Survival could only be compared at three years, and was greatest on the pre-law plots. At Sahara the pre-law percent survival after 10 years was greater than that of the post-SMCRA plantings after only 8 years. The pre-law trees were taller, with substantially greater values than those extrapolated to 10 years for the post-SMCRA trees. Pre-law oaks at Freeman and Sahara, on which early measurements were not taken, formed forest stands 30 years after planting. It is doubtful that post SMCRA oak plantings will be so successful.

Of the possible reasons for the apparently better performance of the pre-law versus the post-SMCRA plantings, several seem consistently evident. One is soil compaction resulting from traffic by heavy machinery during grading operations, and consequent limited root-system development (Philo et al. 1982, Josiah 1986, Vance et al. 1987). Little is known of the effect of compaction on root-system development of eastern hardwood trees, or of rooting depths of these species. There was no reason to think root systems were limited on pre-law spoils, other than on a limited acreage of acidic or toxic materials, and roots were scarcely studied. In observations of fresh road cuts across forested mine banks, woody roots were always found at the bottom of the cuts, ten or more feet deep.Compaction effects can otherwise be recognized. One such effect is that while little or no differences in tree survival and height related to slope were found in more than 30 studies on pre-law ungraded mined lands (Limstrom 1960), and we have similar unpublished results from an equal number of pre-law plots, major differences were found in the Freeman study. Moisture availability, often a function of slope, is greatly affected by grading. Runoff from compacted soils would increase moisture availability and tree performance on lower slopes. Herbaceous cover was also relatively well developed on the lower slopes.

Pasture-type ground cover has been shown markedly to limit tree survival and growth (Philo et al. 1983, Ashby et al. 1988, von Althen 1989). Ground cover was an experimental variable in the study at CONSOL and the factor having the greatest effect on tree performance. Better herbicide practices for growing trees in reclamation are likely needed. More work is also needed on suitable ground cover species in which to plant trees, with tall fescue clearly a species to avoid (Vogel et al.1984).

Table 6. Survival and average height of ash, black walnut seedlings, and black walnut seed planted in 1947 at Freeman and at Sahara. Typical pH values are listed.

Mine Site and Treatment	Survival (%)			Height (cm)		
	Ash	Black Walnut	Black Walnut Seed	Ash	Black Walnut	Black Walnut Seed
Freeman, ungraded banks	3-year data[1]			8-year data[2]		
Black locust cover, pH > 7.0	95	84	65	189	488	469
Shortleaf pine cover, pH > 7.0	97	97	81	125	119	125
Sahara	10-year data[3]			10-year data[3]		
Ungraded, pH < 4.0	77	27	32	305	183	122
Partially leveled, pH > 6.4	83	44	71	396	305	244

[1]Deitschman 1950. Three-year survival in the 1981 Freeman planting on graded spoil was 92% for ash, 25 % for black walnut seedlings, and 3% for black walnut seed.
[2]Boyce and Neebe 1959.
[3]Deitschman 1956.

The non-significant effects of fertilizer on tree growth at CONSOL likely reflect both an absence of deficiencies in the minesoils for those elements and an adverse effect on tree growth of more vigorous growth of the ground cover when fertilized.

Several factors affected the tree performance at Sahara. Although survival was comparable to that at CONSOL, growth was less. The relatively uniform fescue sward on a highly compacted rooting medium (Josiah 1986) was probably a major factor. Another major factor for the black walnut was deer damage, especially buck rub on rows of trees within the fescue meadow. Tops were broken off and trees were delimbed. This damage was so extensive that the measurements of walnut height in early fall 1988 were repeated in early spring 1989. Deer damage was evident on 76% of the saplings. The walnut, ash and oak had some browse damage. Although plantings in another study with alternating walnut and autumn olive of good size were browsed, they had only moderate buck rub damage.

A major factor adversely affecting tree growth, especially red oak, on the post-SMCRA plantings at Freeman was very extensive vole damage in 1984. The trees survived mainly as sprouts and the growth of trees relative to the herbaceous cover was set back and has not yet recovered. Some deer browsing on these rows of trees in the grassy meadow was observed.

Conclusions

Although compaction was not an experimental variable in these studies, the relatively poor tree survival and growth as compared to pre-law plantings or to those on ripped ground or ungraded sites in other studies indicate that grading limited tree growth. Grading brought about significant effects of slope position, in contrast to pre-law lands. Adverse effects of pasture-type ground cover were clearly evident, both directly as shown by herbicide effects and indirectly by enhancing animal populations. Further attention needs to be given to the extensive damage caused by animals to trees in reclamation. Well-spaced trees on grassy meadows serve as deer parks. The meadows are also ideal habitats for voles (field mice). Populations of deer have increased greatly in recent years and thus the damage they cause has increased. Unless

needed control measures are instituted, survival and growth of walnut or other trees favored by these animals will be limited.

Failure to realize the need for extensive and continuing weed control may hinder reclamation with trees. The remarkable increases in black walnut growth with annual simazine sprays compared to mowing or limited herbicide application (von Althen 1989) need to be evaluated for mine lands.

Problems attributed to compaction may actually be caused by inadequate ground cover control. Some alternatives of less damaging ground covers are well illustrated by the CONSOL results. Still other species, such as red fescue (Festuca rubra L.), have promise (Ashby et al. 1989).

The role of fertilizers in tree plantings continues to be ambiguous. If fertilizers increase ground cover growth, they may do more harm than good. Fresh minesoils have good nutrient reserves and using an overburden mixture in place of the original topsoil could reduce a need for fertilizer. Allowing rock fragments on the soil surface would decrease erosion and reduce the need for ground cover plantings under present regulations (Ashby et al. 1984). Coarse textured materials also withstand compaction better than clay loams or silty clay loams found in southern Illinois.

Properly handled, mined lands are attractive sites to achieve alternative uses for trees. These uses include plantings for renewable energy (biomass) production and to help solve world CO_2 and air pollution problems. These promising uses of trees should be combined with new opportunities in reclamation suggested in part by this paper.

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